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NOTES

ON

TORPEDO FUZES.

UNITED STATES NAVY.
BUREAU OF ORDNANCE

BY

LIEUT. G. A. CONVERSE, U. S. NAVY.

Newport, R. I.

1875.

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NOTES ON TORPEDO FUZES.

TORPEDO FUZES.

Definition.—The term Fuze is generally applied to any contrivance used to ignite, at a desired time, a distant charge of explosive material.

Classification.—Torpedo fuzes may be classified according to their mode of operation, as *Percussion, Friction, Chemical, and Electric Fuzes.*

PERCUSSION FUZES

Comprise What?—Percussion fuzes comprise all fuzes in which the flame is produced by a blow on some fulminating compound.

The fulminate is generally used in the form of the ordinary percussion cap, percussion cannon-primer, or in a similar form.

The blow may be produced in various ways:

(1.) By releasing a compressed spring which acts on a hammer.
(2.) By the dropping of a weight.
(3.) By the impact of a moving body.

(1.)

Singer's System.—Plate I, Fig. 1, shows a single percussion apparatus. A is the trigger, B the hammer, C a spiral spring, D an iron firing rod having a percussion cap on the end, E a thumbscrew holding the firing rod in position, F a composition rod having lugs G G for the hammer and firing rod to work through, and H a face plate to serve as a fulcrum for the trigger.

Fig. 2 shows the method of multiplying the number of points of ignition.

Fig. 3 represents the apparatus in position, and shows the manner of working it; K is a cast-iron cap placed on top of the torpedo, and retained in position by a projecting ring *r r*. The cap is attached by means of a wire to the triggers.

When the torpedo is struck by a passing vessel, the cap K is knocked off, and in falling pulls out the trigger. The hammer being released, is forced up by the spring and strikes the end of the firing rod, thus exploding the cap. The entire lock should be covered to protect it from rust, and to prevent the accumulation of marine grass and shell-fish.

Application.—Apparatus of this form can only be used with buoyant torpedoes. It was used extensively by the Confederates, and with greater effect than any other variety of torpedo. It possesses the merit of simplicity, and would not be likely to get out of order. But it is best to avoid as far as possible the use of springs in torpedoes which are to remain in position any length of time.

CLOCK-WORK SYSTEM.—Plate I, Fig. 4, shows the general features of this form of apparatus.

It consists of a train of clock-work carrying on the axis to which the main-spring is attached a small wheel graduated as represented, and having a recess cut in its circumference.

Fig. 5 shows the details of the exploding mechanism, N is a cylinder containing the hammer B and the spring C; D is the cone-seat, and E the cone of a musket, on which is placed the percussion cap F. G is a lever, the toe of which catches under the collar H on the hammer; I is a small stud in the lever which rests on the circumference of the wheel K, and thus keeps the hammer up. As the wheel K revolves, the recess L is brought under the stud I, which drops into it; thus allowing the arm of the lever G to descend, and releasing the hammer which is forced down on the cap by the spring G.

The wheel K can be set at will like an alarm clock, thus securing the action of the hammer at any desired time.

Application.—This form of fuze, which is in reality a time-fuze, is used in torpedoes which are intended to be exploded after a given interval of time, *e. g.*, "current or drifting torpedoes." Torpedoes of this class are placed in a river or tide-way, and left to drift towards the object to be attached; and the fuze must be so constructed as to explode when they have reached that object, that is, after a given length of time, depending on the strength of the current and the distance. In torpedoes designed to blow up bridges and obstructions in rivers, this form of fuze can be used to advantage.

McEvoy's System.—Plate I, Fig. 5. A represents an arm pivoted in the center, and having at one end a many bladed screw-propeller of sheet-tin; B C is a worm attached to the propeller, and turning with it. D is a hammer retained at full cock by the lever E, which is secured to the sleeve F. This sleeve travels freely on the arm A. The outer end of the lever has a curved arm which works in the thread of the worm. G is a percussion primer. A few turns of propeller withdraws the lever E, and permits the hammer to fall on the primer.

Application.—The apparatus is designed to be used with "current or drifting torpedoes." As long as the torpedo is free to move with the current or tide, the propeller will not turn; but as soon as its motion is arrested, the propeller commences to revolve, and soon releases the hammer and causes the explosion.

This form has an advantage over the clock-work system, as it is not likely to be exploded except when in actual contact with an obstacle; and as the explosion occurs immediately upon arresting its progress, there is no opportunity for an enemy to remove it before the explosion takes place.

(2.)

The Weight System.—Plate I, Fig. 6. A is a tube about 2½ inches in diameter running longitudinally through the torpedo case. B is a metallic plug secured in the end of the tube, and serving as a seat to an ordinary musket-nipple C. D is a tube used as a hand-hole in adjusting the cap. E is an iron ball about 2 inches in diameter held in position by the pin F. This pin passes through a stuffing box at G, and has a laniard H attached to it.

The air-chamber in the end of the torpedo causes it to take an upright position. A slight jerk on the laniard H withdraws the pin F and permits the ball to fall on the cap.

Application.—Fuzes constructed on this principle have been used successfully with spar torpedoes; for instance, in the destruction of the "Albemarle."

A modification of the form was also used on the powder-boat "Louisiana."

Although successful in the case named above, this form of fuze is not considered as well adapted to offensive torpedoes. It would probably only be employed in cases where it was necessary to improvise a fuze from such material as could be easily obtained.

(3.)

THE CONTACT SYSTEM.—This system requires a fulminating compound more sensitive than that used in either the percussion cap or cannon-primer. A very good compound has been prepared by Mr. Hill, chemist to the torpedo station. It is made by finely powdering and mixing together, under alcohol, the following ingredients:

Potassic Chlorate	($K\,Cl\,O_3$) . . .	60.50 per cent.
Antimonius Sulphide	($S\,b_2\,S_3$) . . .	33.50 per cent.
Red Phosphorous	(P) . . .	6.00 per cent.

Plate I, Fig. 8, shows the form of the primer usually employed. A is a small paper tube, one end of which is stopped with a wad of tissue-paper and dipped in wax. The other end is glued into the hole in a small disc of wood, B. The tube is then filled with fine rifle powder, and a piece of tissue-paper is glued over the disc to confine the powder. The cone C is made by taking a piece of thick paper, cut as shown in Fig. 9, and gluing the two edges E E together. This cone is turned base up and filled about one-third with ground quartz. The remaining space is filled with the composition described above, which has previously been dried and pulverized. The upper surface of the disc having received a little glue, is now placed on the base of the cone and held there until the glue sets. The primer is then coated with shellac.

Plate I, Fig. 10, is the stock used with the primer; all the parts being made of gun composition, or of some similar metal not easily affected by sea water. A A is the stock, B a plunger, C the primer seat, and D a spiral spring which keeps the plunger from coming in contact with the primer head until force is applied; E is a thin cap of soft well-annealed copper called the water-cap. F is a safety

cap which is left on till just before the torpedo is placed into the water.

To prepare for use, the primer seat is unscrewed and the stem of the primer inserted in the hole in the seat till the head of the primer rests on the top. The spiral spring is then placed in position and the seat screwed into the stock.

When struck, a slight blow causes the water cap to yield, and forces the plunger down on to the primer, exploding it.

Application.—In all cases where fuzes of this kind have been used, it is customary to employ several, and place them in any part of the torpedo, that could by any chance touch the object to be destroyed. They are particularly applicable to buoyant torpedoes and spar torpedoes. They seldom, if ever, fail; are simple in construction and action; and are not liable to get out of order, even when left submerged for a long time. They are, however, extremely sensitive, and must be handled with great care.

FRICTION FUZES

COMPRISE WHAT?—Under this head are classed all fuzes in which any specially prepared composition is ignited by heat, generated by friction.

The heat may be caused by—

(1.) The friction of a metallic surface on the composition.

(2.) The friction of the particles of the composition on each other.

(1.)

CANNON PRIMER FUZE.—Plate II, Fig. 1, represents an ordinary friction cannon-primer. A is a tube of thin brass, filled with rifle powder; B a projecting tube of the same metal, filled with a friction composition; C a stout wire, the serrated end of which is imbedded in the friction composition; and D an eye formed in the other end of the wire, to which is hooked a lanyard.

When the lanyard is pulled, the friction of the rough wire against the composition produces sufficient heat to ignite it, and the flame is communicated to the powder in the long tube.

Fig. 2 shows a method of arranging several of these primers in a form well suited to the ignition of torpedo charges. A is a piece of iron pipe about 1¼ inches in diameter. Several holes are bored transversely through the pipe, the axes of these holes being situated in different planes. The long tubes of the primers are put into these holes, and each primer secured as represented in the figure, to prevent it from falling out. Small stout wires, B, B, are fastened to the eyes of the primers, and the ends passed out through small holes in the plug C, and made fast to a ring D. The holes through which the wires pass may be filled with wax, resin, pitch, or any similar substance.

The firing lanyard is bent to the ring D. A strong pull explodes all the primers at the same time, and ignites the torpedo charge in several points.

Friction Torpedo Fuze.—Plate II, Fig. 3. A is a metallic plug screwing into the torpedo case; B a stout brass wire passing freely through the plug A, and C a water-cap of soft, well-annealed copper, soldered to the plug and brass rod. D is a rod of iron firmly secured to the plug A, to which are soldered the copper tubes E, E, E. F F is a wire serrated at the points within the copper tubes, and secured to the rod B. The tubes are filled through the holes G, G, G, with friction composition, which is put in wet. Pieces of thick paper are then pasted around the tubes to retain the composition in place.

The action is exactly the same as in the fuze above described.

(2.)

Pressure Fuze.—Plate II, Fig. 4. A is a metallic plug to be screwed into the torpedo case; B B are rods of iron firmly secured to the plug; C is the firing rod of brass, passing freely through the plug, A, and having slots, about an inch long, cut through it at the points *c c c;* D D D are iron pins secured to the side rods, and passing through the slots in the firing rod; *e e e* are wooden supports, through which the firing rod passes, the object being to prevent vibration of the rod; F is the water cap and G a safety pin, passing through the plug and rod. The slots in the firing rod are filled with friction composition, put in wet, and coated with collodion.

The firing lanyard has two legs, the shorter of which leads through

an eye secured to the torpedo head, and is made fast to the safety pin; the other leg is made fast to the eye of the firing rod. On pulling the lanyard, the strain first comes on the short leg, and withdraws the safety pin, after which the firing rod yields. The composition is compressed between the ends of the slots and the pins, and the friction of the particles on each other ignite it.

Composition for Friction Fuzes.—Professor Hill recommends the following composition for use in friction fuzes:

Potassic Chlorate,	($K\,Cl\,O_3$) . .	44.44 per cent.
Manganic Oxide,	($M\,O_2$) . .	44.45 "
Red Phosphorous,	(P) . .	11.11 "

The ingredients must be finely powdered, mixed under alcohol, and used while wet.

Application of Friction Fuzes.—These fuzes have been used in exploding spar torpedoes with satisfactory results. The lanyard enables an operator to explode the charge at will—an advantage over the contact system.

When improvised buoyant torpedoes are used for the defence of rivers or narrow entrances to harbors, friction fuzes can be employed. In such cases, torpedoes would be moored in a line across the channel, and the firing lanyard of one torpedo made fast to the case of the next. A passing vessel comes in contact with the bight of the lanyard, and so explodes the torpedo. (Plate II, Fig. 5.)

Ground torpedoes, fitted with friction fuzes, can be advantageously employed in connection with buoyant torpedoes. The firing lanyard is made fast to the buoyant torpedo, and the ground torpedo placed some distance from it—about 30 feet down stream, in tide ways. An attempt to remove the buoyant torpedo pulls the firing lanyard, and explodes the ground torpedo. (Plate II, Fig. 6.)

CHEMICAL FUZES.

Definition.—Chemical fuzes are those in which substances separated until required for action are then brought into contact, and unite chemically with the evolution of heat and production of flame.

Such action occurs when sulphuric acid is brought into contact with a mixture of equal parts of potassium chlorate and loaf sugar.

SULPHURIC ACID FUZE.—Plate III, Fig. 1, shows the general form of the fuze. A is a metallic plug, fitted to screw into the torpedo case, and B a tube of lead, having the upper end closed and the lower end soldered to the plug; C is a glass tube filled with sulphuric acid. This tube is placed within the lead one, and the space between the two filled with a mixture of equal parts of potassium chlorate and loaf sugar. A disc of paper is placed over the mixture, and the magazine, D, is then filled with rifle powder, and closed by a piece of thin zinc, E.

A blow or a strain bends the lead tube, and breaks the glass, liberating the acid, which immediately unites with the surrounding mixture. The flame produced fires the powder in the lower part of the fuze, which explodes, blowing off the zinc bottom, and communicating with the torpedo charge.

Fig. 2 is a safety guard, designed by Professor Abel, chemist to the English War Department, for use with chemical fuzes. It consists of two semi-cylindrical pieces of iron, which, when placed together, form a case sufficiently large to enclose the lead tube of the fuze. B is a ring, fitting snugly over the two segments, and holding them firmly together; C is a pin to hold the ring in place. Before lowering the torpedo into position, the pin C is withdrawn, and when it is desired to render the torpedo active, the ring B is pulled off by a line attached to it, and the iron segments fall apart, leaving the lead tube exposed.

Fig. 3 is a stop cock suggested by Captain Stewart, R. E., as a means of shutting off the fuze from the torpedo charge, and thereby preventing it from exploding, in case the fuze should be accidentally ignited. When turned as shown at *a*, the fuze connects directly with the charge. When turned as at *b*, communication with the charge is shut off, and an escape hole opened. This escape hole is to be covered with a water-proof plaster, which will prevent moisture from entering, but which offers no material resistance to the escape of the gas from the fuze. This arrangement, inserted between the lead tube and brass plug, would effectually answer the purpose for which intended. It might also be used with the contact system of percussion fuzes.

Application.—The chemical fuze has probably been used more extensively than any other for igniting torpedoes and land mines. When used with buoyant torpedoes, it is usually applied as a contact fuze. Professor Abel, however, has modified the form above described, and, by attaching a line to an eye screwed into the top of the lead tube, proposes to use this fuze in the manner described under "Friction Fuzes," and shown in Fig. 5, Plate II.

When employed to explode spar torpedoes, several of them are screwed into the head of the case, and used as contact fuzes.

Remark.—The action of the sulphuric acid fuze is somewhat sluggish, particularly when it has been manufactured for any length of time, as the mixture around the glass tube is apt to become caked. Experiments show that the addition of ferro-cyanide of potassium, or sulphuret of antimony, will hasten the ignition. If to equal parts of potassium chlorate and loaf-sugar, one third (by weight) of ferro-cyanide of potassium be added, the ignition is instantaneous.

Other Fuzes proposed.—Captain Hardy, R. A., suggests another variety of chemical fuze, in which ignition shall result from the well-known action of water on potassium or sodium. It is probable, however, that the great difficulty of keeping potassium or sodium free from superficial oxidation would render these materials comparatively worthless for this purpose.

EXPLODING APPARATUS FOR HARVEY'S TORPEDO.—This apparatus consists of two essential parts, the firing bolt and priming case.

The Firing Bolt.—Plate III, Fig. 4. The bolt is made of iron, and is of the form shown in the figure, the lower portion being represented in section. At the points *a*, *a*, *a*, are cut scores which are filled with a packing made by winding many turns of whity-brown thread. This packing having been thoroughly saturated with a lubricating mixture,* is compressed to the proper size by being forced into a tube of standard diameter.

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* This mixture is composed of hog's lard (free from salt,) 3 parts; beeswax, 1 part; and neats-foot oil, 1 part.

The cavity B, in the lower end of the bolt, is filled with a chemical mixture used to ignite the priming material.

The mixture is made by finely pulverizing and mixing together—

Potassic Chlorate	17.0 parts.
White Sugar	4.5 "
Nut Galls	1.5 "

Small quantities of the mixture are poured into the cavity, and thoroughly packed down by means of a wooden mandrel and small mallet, until the entire charge, which weighs 4.5 grammes, has been used. A wad of cotton is placed over the mixture. A small glass bulb C, containing a few drops of sulphuric acid, is wrapped in a thin piece of muslin, and placed in the mouth of the cavity. The bulb is covered with a piece of cotton to protect it, and the end of the bolt is closed by a capsule of lead.

The safety-key D prevents the bolt from being accidentally forced too far into the priming case and exploded.

The bolts are fitted for starboard and port torpedoes, and are marked S and P. They can also be distinguished from each other by the angle which the safety-key D makes with the head of the bolt.

The slot E in the head of the bolt is for a lever to work in.

The Priming Case.—Plate III, Fig. 5. The metallic plug, A, A, is fitted to screw into a bouching in the torpedo case. To this plug is secured a tube of thin brass B, B, fitted with a screw-cap C, at the bottom. This case is filled with rifle powder or some stronger explosive. The inner tube, D, D, also made of brass, is for the firing bolt to work in. At the bottom of this tube is a pointed steel pin, E. On one side of the tube, and near the base of the pin, is a small hole, F, which is closed by a piece of thin brass or copper. The object of this hole is to provide an escape for any water which may have collected in the bottom of the tube; for when the firing bolt is pushed down the water will force the thin covering off and escape into the priming case. If water was present, and there was no outlet provided, it would be impossible to drive the firing-bolt home.

How used.—The priming-case is screwed into the torpedo, and the firing-bolt placed in the inner tube and pushed down as far as the safety-key allows. The contact levers are then arranged. After the torpedo is launched the safety-key is withdrawn. When the levers are struck the firing-bolt is forced down. The steel pin penetrates the lead capsule, breaks the glass bulb, and pierces the chlorate mixture. The sulphuric acid and the mixture unite chemically and fire the priming material, which, in turn, ignites the charge.

Remarks.—Fig. 6 shows a brass safety-guard, which is used in handling the bolts. It is placed over the head of the bolt and the thumb-screw turned till its point is firmly caught in a small hole in the bolt. The projecting legs of the guard prevent the bolt from being inserted too far into the priming-case, even should the safety-key be left out. The manner of fitting this guard insures its removal before launching the torpedo, as the after lever cannot be shipped while the guard is on the bolt.

The bolts are packed and issued to the service in boxes called magazines.

Each magazine is fitted with two brass tubes for the reception of bolts—one S and one P.

All bolts are the same size. Those intended for the large torpedoes should work with a pressure of from 30 to 40 lbs.; those for small torpedoes should require from 15 to 20 lbs.

The bolts are easily kept in order by turning them occasionally in their tubes in the magazine. For this purpose the safety-guard will be found a convenient handle. Should they work too easily, a few turns of thread should be added to the two lower packings. Should they work too stiffly, revolve them several times on their tubes until the packing has become compressed.

The priming-cases, when not filled with a dangerous explosive material, can be stowed away in torpedoes until required for use. The inner tube is closed by a long wooden plug. This plug has a cavity in the lower end which is filled with a greasy composition. The plug is forced down until the steel pin is completely surrounded by the composition; the object being to prevent the pin from rusting and to keep dirt out of the tube.

ELECTRIC FUZES

Comprise What?—Under this head are included all fuzes which are ignited by the agency of electricity.

Causes of Ignition.—In electric fuzes the ignition may be caused by—

(1.) The shock or blow of disruptive discharge acting on a sensitive composition.

(2.) The heat generated by the passage of an electric current over a conductor of high specific resistance.

Service Fuzes.—All service fuzes manufactured at this Station are of the same general form.

They consist of an igniter, so called, and a paper tube filled with rifle powder.

Plate IV, Fig. 1, shows the form and manner of making a fuze. A is the igniter, its wires being pressed into grooves on the sides of the plug B. Both the igniter and plug are thrust into a paper tube, C, C, which is secured to the plug by being choked into the score, D, D, by means of two turns of stout copper wire. The paper case is filled with rifle powder and the other end closed by a thin cork, which is coated with collodion, to hold it firmly in its place. The whole case is given two coats of shellac.

The Igniter.—The object of the igniter being to produce the flame necessary for the ignition of the powder in the tube, its construction depends entirely on the variety of machine with which it is to be used.

How distinguished.—Each variety of igniter and its corresponding fuze is given a name and a distinguishing color, in order that no mistake may be made in selecting the proper one for a particular kind of machine.

Water Proof.—All igniters are rendered water proof by dipping them in shellac, and then in Farmer's water-proof compound, and after this has hardened, again in shellac. When treated in this manner, igniters have been placed in water, and allowed to remain for more than six months without any injurious effect.

FOR FRICTIONAL MACHINES.

Name, "F;" Color, Black.

Principle.—If a slight break is made in a metallic conductor, which communicates with the poles of a frictional machine, and the machine is then set in motion, a disruptive discharge, accompanied by a spark, takes place between the ends of the conductor. This discharge will not, under ordinary circumstances, ignite gunpowder, but if a sensitive composition be placed between the ends of the conductor, the force of the shock or blow will ignite it. All fuzes used with frictional machines are constructed on this principle.

Sensitive Composition.—The following composition, prepared by Mr. Hill, chemist, is used in all igniters made at this Station for use with frictional machines:

Potassic Chlorate,	$(K\ Cl\ O_3)$ . .	45.00	per cent.
Antimonious Sulphide,	$(S\ b\ S_3)$ . .	20.75	"
Red Phosphorous,	(P) . .	5.75	"
Carbon, (black lead)	(C) . .	28.50	"

All parts to be finely powdered, mixed under alcohol, used when wet.

Form of Igniter.—Many forms of igniters have been used at this Station, the simplest and best being that of Lieutenant Bradford.

Fig. 2. A is a plug having a score around it, about one-third the distance from the lower end. On opposite sides of the plug are cut grooves longitudinally, and of sufficient size to receive the wire. These grooves are joined by another, two diameters of the wire deep, cut across the top of the plug—a piece of cotton-braided copper wire, No. 20, B. W. G., about eight inches long, is used. The covering is cut at the middle, and shoved towards each end, and a square-cornered bight formed at that part of the wire bared. This bight is placed over the plug, and the wire pressed well down into the grooves. A seizing is placed around the score of the plug to keep the wires in position. The wire on the end of the plug is cut with a small circular saw of a thickness equal to the distance it is desired to have between the ends of the wires. The score B thus made

is filled with the sensitive composition, above described, which when dry is coated with collodion, the object being to keep the composition in place, and, in a measure, to protect it from accidental ignition by friction. The plug is next glued into the wooden case C, being countersunk a little. The case is filled with rifle powder, and closed by a thin cork. The cavities in the ends are filled with water-proof compound.

The outer ends of the wires are well separated, and care should be taken that they do not approach. When connected to a machine, should the distance between the conducting wires at any point be less than that made in the ends of the plug, disruptive discharge occurs at that point, and the fuze is not ignited.

Distance between Discharging Points.—The length of the gap in the wire necessary to produce the best effects, the sensitive composition remaining the same, depends on the power of the machine used. The distance adopted at this Station is one-sixteenth of an inch, this distance being deemed best for general use, as machines of ordinary power can explode several of these fuzes in the same circuit.

FOR MAGNETO-ELECTRIC MACHINES.

Name, " M, E;" Color, Red.

Principle.—If certain substances capable of conducting electricity, but offering very great resistance to its passage, be used to bridge over a break made in a metallic conductor which joins the poles of a magneto-electric machine, then, on the passage of the current, these substances become heated, and will ignite sensitive compositions, or fine gunpowder, in contact with them.

Plumbago, sub-sulphide of copper, or a mixture of charcoal and resin may be used for this purpose.

Form of Igniter.—Fig. 3 shows the form of igniter designed by Lieut. Bradford and adopted at this Station.

The plug A has a score around it, one-third the distance from the bottom. On top of the plug is a groove, one diameter of the wire deep, which joins two similar grooves cut longitudinally on opposite sides of the plug. No. 20, cotton-braided copper wire is used. The insulation is cut at the middle of the piece of wire and shoved towards the ends, and a square-cornered bight formed at the bare part of the wire. This bight is placed over the plug and the wire is well pressed down into the grooves. The insulation of the wire is then pushed close up to the base of the plug and the wires twisted together, as shown in the figure. The wire across the top of the plug is barely severed by being cut with a small three-cornered file. A soft lead pencil is rubbed in the groove made by the file, and sufficient plumbago adheres to the wood to make a complete bridge between the ends of the two wires. The groove is filled with mealed powder, which is well pressed down and coated with collodion to retain it in place. The plug is glued into the case, B, being slightly counter-sunk. The case is filled with rifle powder and closed by a thin piece of cork. The cavities in the end of the case are filled with water-proof compound, and the whole igniter rendered water-proof by the process before described.

THE BRIDGE—LENGTH.—In fuzes of this class, in which plumbago is used for the bridge, experiment shows that the distanee between the ends of the metallic conductors should in no case exceed 1-20th of an inch. A less distance is to be preferred; the limit depending only on the ease and uniformity with which the plumbago can be inserted.

RESISTANCE.—The amount of resistance offered to the passage of the electric current by fuzes constructed on this principle varies greatly, even when the utmost care is taken in their manufacture. Those in which the interval between the ends of the wires is very small have measured as low as a 1,000 Ohms; while others, which fired equally well with the various magneto-electric machines, often give resistance as high as 250,000 Ohms.

FOR DYNAMO-ELECTRIC MACHINES.

Name, " D, E;" Color, Shellac.

PRINCIPLE.—Metallic conductors which offer great resistance to the transfer of electricity become heated while such transfer is taking place. The amount of heat produced depends on the resistance of the conductor and the strength of the electric current.

Small conductors offer great resistance; and when a very small wire of platinum, German silver, iron, or other metal of high specific resistance is used, an electric current of moderate strength produces sufficient heat to render quite short lengths of the wire incandescent.

Farmer's dynamo-electric machine furnishes a current strong enough to produce this effect on very small wire of any metal having a moderately high specific resistance.

FORM OF IGNITER.—Fig. 4, Plate IV, shows the form of igniter which has been issued to the service. It was designed by Lieut. Bradford.

Two pieces of cotton-braided copper wire, No. 20, about six inches long are used. The insulation is removed from one end of each wire for the distance of an inch, and the bared ends are then pressed into grooves on opposite sides of the wooden plug, A. The insulation is pushed up on the wires close to the base of the plug, and the wires twisted together as represented. The short ends of the wires are cut off so that they project one-eighth of an inch beyond the end of the plug. The ends of these wires are split, by means of a small saw, in the direction of a plane passing through both. The distance between these ends having been verified and made exactly 3-16th of an inch, a piece of platinum silver wire is stretched between them and secured by closing the splits and soldering them. A small wisp of gun cotton is wrapped around the platinum silver wire, after which the ends of the copper wire are slightly pinched together, to take all strain off from the bridges. The resistance of the bridge is now measured, and if found to be within the prescribed limits, the igniter is completed. The plug is glued into a wooden case, B, which is filled with rifle powder and closed with a disc of cork. The cavities are filled with water-proof compound, and the whole igniter rendered impervious to water by the method already given.

Fig. 5 shows the improved form of igniter now issued to the service for use with Farmer's Dynamo-Electric Machine. It was designed by Mr. Wilkes.

A is a small wooden plug having a score around it near the center, and also having the lower end rounded as shown in the figure. On opposite sides of the upper rim are cut grooves leading into holes bored through the lower rim which converge towards the center of the plug at the base. Two pieces of cotton-braided copper wire, No. 20, about six inches long are taken, and the insulation coated with shellac. When dry, the wires are thrust through the holes in the base of the plug, and the ends well pressed into the side grooves. The long ends of the wire are twisted together, and the inner ends are cut off so that they project about an eighth of an inch. These short ends are then split, by means of a small saw, and the distance between them made exactly three-sixteenths of an inch. Platinum-silver wire is inserted in the splits which are closed and soldered. A wisp of gun-cotton is wrapped around the platinum-silver wire, and the ends of the copper wires slightly bent towards each other to relieve the bridge from strain. The resistance of the bridge is measured. A copper case, B, is filled about three-quarters full of rifle-powder and the wooden plug shoved into it as far as it will go. The case is now spun down over the end of the plug and choked, as represented. The igniter is made water-proof by the process already described.

OBSERVATIONS ON THE "D. E." IGNITER.

The Bridge, Material.—The material of which the bridge is made should have a high specific resistance, and this resistance should not increase greatly when the metal is subjected to a high degree of heat. It should not be liable to corrosion, and should possess considerable strength.

German silver, platinum, or an alloy of platinum and silver is generally used.

German silver is liable to corrode, and is therefore objectionable for torpedo fuzes.

The resistance of platinum increases considerably as the metal becomes heated by the passage of the electric current, a circumstance which must be taken into consideration in computing the strength of current necessary to produce the degree of heat required to ignite a given priming material.

Experiments are constantly being made with different alloys with a view of finding one which shall fully meet all the requirements. An alloy of one part of platinum and two parts of silver gives more satisfactory results than any metal yet tried, and is used in all fuzes made at this Station.

Diameter.—"This increase of temperature produceed by the passage of the same quantity of electricity over conductors of the same material, but of different section, varies inversely as the square of the cross-section, or the fourth power of the diameter." It follows then, that smaller the wire the less the strength of the current required to render it incandescent. The extreme to which the diameter of the wire can be reduced depends only on the strength which it is necessary to have and the facility with which it can be manipulated. The size adopted is No. 40, its diameter being 0.0023 of an inch.

Length.—To a certain limit, depending on the strength of the current, the amount of heat produced increases with the length (and consequently the resistance) of a conductor.

If it were intended to use only a single fuze with the Dynamo-Electric Machine now issued to the service, it would be advisable to introduce quite a long bridge into each; but as it may often be desirable to connect several fuzes in the same circuit, a short bridge is used so that the aggregate resistance introduced may not exceed the capacity of the machines.

The bridge must not, however, be made too short. The resistance decreases with the length, and if made very short the resistance would not be sufficient to generate the requisite amount of heat. Besides, the bridge being joined to copper wires of comparatively large size, the heat is rapidly conducted away from its ends.

The length adopted for the service igniters is three-sixteenths of an inch.

Resistance.—The service igniter, constructed as above described, with No. 40 platinum silver wire, and a bridge 3-16 of an inch long should give resistance of .42 Ohms. All igniters issued are between the limits .40—.45 Ohms.

PRIMING MATERIAL.—Experiments made to determine the best priming material for the igniters, above described, have given the following results:

Priming Material.	Strength of current required to ignite it.
Mealed powder	0.98 Weber.
Mealed powder and fulminate	0.63 "
Collodion and rifle powder	0.60 "
Collodion and mealed powder	0.60 "
Gun cotton	0.54 "

Besides requiring the least strength of current to fire it, gun cotton is convenient to handle, safe, reliable, and not likely to become displaced, or to deteriorate by storage.

FILLING.—Formerly all igniters issued were filled with a mixture of equal parts of mercuric fulminate and mealed powder. This mixture is very sensitive and powerful, but extremely dangerous. Satisfactory results being obtained by the gun-cotton priming and a filling of fine rifle powder, the latter has been adopted, as it lessens the danger of accident, both in the manufacture and use of the igniters.

THE "D. E." DETONATING FUZE.

Plate IV, Fig. 6, shows the form of the D. E. Detonating fuze used with nitro-glycerine and its compounds—dynamite, &c. It was designed by Lieutenant Bradford.

The plug A has a score around the middle and longitudinal grooves cut on opposite sides. Two pieces of gutta-percha covered wire, No. 22, about ten inches long, are used. About an inch of the insulation is removed from end of each wire. These bared ends are pressed into the grooves on the opposite sides of the plug, and the long ends twisted together, for a short distance, at the base of the plug. The short ends are cut off so that they project only one-eighth of an inch, and are then split by means of a small saw. The bridge of No. 40 platinum-silver wire is placed in the splits, which are then closed and soldered. A wisp of gun-cotton is wrapped around the bridge, and the ends of the copper wires are pinched together slightly, to relieve the bridge from strain.

A copper cartridge case, B, (long drawn calibre, 30,) is filled with mercuric fulminate, mixed with gum mastic. This mixture is put into the case and allowed to dry, when it becomes one solid lump, and the danger of accidental explosion while handling is much diminished.

The outer case C C is made of wood, and is closed at one end, as shown. Into this case is dropped the copper case containing the fulminate, and a wad of gun-cotton is placed over it. The plug A is then inserted, and pushed in as far as it will go, and glued there, the wad of gun-cotton preventing the wires from coming into contact with the copper case, and thereby forming a short circuit. When the glue has set, the space at the base of the plug is filled with gutta percha. The fuze is dipped into boiling paraffine, to render it water proof, this substance being entirely unaffected by nitro-glycerine and its compounds.

FOR VOLTAIC BATTERIES.

Principle.—In the use of voltaic batteries no transfer of electricity takes place unless substances capable of conducting electricity are used to form an unbroken circuit between the two poles of the battery.

As has already been stated, conductors which oppose a resistance to the passage of an electric current become heated while such passage is taking place; the amount of heat generated depending on the resistance of a conductor and the strength of the current used.

In using voltaic batteries the strength of current can be made anything desired by arranging or grouping the cells.

It follows then, that voltaic batteries may be used to ignite any fuze in which there is a secondary conductor or bridge of metal, or any substance of high resistance.

Strength of Current Required.—The strength of current required to ignite fuzes of different classes can be determined by experiment alone; for the material and dimension of the bridge and the nature of priming substance must be taken into consideration, and a slight change in the condition of either will materially

increase or decrease the strength of the current necessary to fire a fuze.

For D. E. Fuzes.—Experiments made with the service D. E. fuze show that under ordinary circumstances one cell of Station battery, or its equivalent, will be ample to insure its ignition.

For M. E. Fuzes.—The results obtained from trials with M. E. fuzes have varied greatly, but it may be stated that when the fuzes are carefully made, twenty-five cells of the Station battery, or its equivalent, will rarely fail to ignite them.

IMPROVISED FUZES.

Cases may arise when, for the want of the regular service igniters or fuzes, it may be necessary to improvise substitutes from materials at hand or ordinarily on board ship.

With a little care very good fuzes can be made from materials readily obtainable by any one of the following methods.

Lieut. Bradford's Fuze.—Plate V, Figs. 1 and 2. Make a cylindrical wooden plug which will fit snugly into a metallic cartridge case. Through this plug A bore two holes, and through them pass the two ends, a piece of copper, brass, iron, or steel wire, *b*, *b*, hauling the bight close down to the plug and hammering it into the wood. Wedge the wires firmly at *c*, *c*, so that they cannot move. Cut the hammered bight of the wire with a three-cornered file, barely severing it. Rub this groove with a soft lead pencil, taking care to make a perfect bridge of the plumbago from one terminal to the other. Take the composition from the head of a common cannon primer and press it into the groove made by the file, and paste a piece of thin paper over it to keep it in place. Fill the copper-case nearly full with rifle powder, insert the plug into the case as far as it will go, and secure it there by driving any pointed instrument several times through the case and into the plug. Paste a piece of paper around the joint of the case and plug, as shown in the figure, and render the whole igniter water-proof by dipping it into melted wax, shellac, or simliar material.

When carefully made, fuzes of this kind should fire with all magneto-electric machines, with Farmer's large Dynamo-Electric Machine, and with 12 cells Station battery, or its equivalent.

Lieut. Barber's Fuze.—Plate V, Figs. 3 and 4, show the form of this fuze. A is a metallic cartridge case, and B a piece of cork through which is thrust the lead pencil C, and the two copper wires *d d*. E is a thin piece of wood which keeps the wires from turning. The wires are securely lashed at the points *f f f*.

In making a fuze on this plan the following points must be observed:

The ends of the wire must be in close contact with the plumbago of the pencil.

The thickness of the plumbago at contact points must not be too great.

The wires must be securely fastened to prevent the ends from becoming displaced.

This fuze should always fire with Farmer's large Dynamo-Electric Machine, and with 12 cells of Station Battery or its equivalent.

Lieut. Moore's Fuze.—Plate V, Figs. 5 and 6. In this fuze the bridge is formed by the lead of an ordinary pencil; a small piece of the wood of the pencil being left in contact with the lead, on one side, for the purpose of strengthening it. Two pieces of small copper wire, and a cylindrical wooden plug having two pairs of small holes bored through it longitudinally are used. Each wire is bent into the form of an ∩, with one leg longer than the other. The bridge is laid across the end of the plug, the lead being placed upmost, and the ends of the wires are passed down through the holes in the plug; one wire occupying each pair of holes. The bight of the wires pass over the ends of the bridge, and the short end of each wire is twisted around its own longer end at the base of the plug. The bridge is thus held firmly in position, and a good connection is formed between the lead and the wires; especially if the latter be flattened at the point of contact. The lead part of the bridge is now scraped until its diameter is reduced as much as possible without risk of cracking it.

A copper cartridge case is filled nearly full of rifle powder, and the plug inserted into the open end and secured there by driving a pointed instrument several times through the case and into the plug. A little practice will enable one to construct fuzes of this kind which will be nearly uniform in resistance and quite reliable.

This fuze fires with Farmer's large Dynamo-Electric Machine and with 12 cells of Station Battery, or its equivalent.

Notes.—Fuzes in which the bridge is made of plumbago can easily be tested by means of a Farmer's Machine, or Voltaic Battery, before the case is filled with powder. The bridge should quickly become incandescent. After testing, the wire should be pressed well down on the plumbago, as the contact is apt to become impaired when the bridge has been heated.

It is found by experiment that the lead of hard pencils offers much greater resistance than that of soft ones. The average resistance of fuzes constructed on the plans above described, using soft lead pencils, was about 2 Ohms, while hard pencils gave a resistance of over 8 Ohms. For Farmer's Machine and Voltaic Batteries of low internal resistance soft pencils are to be preferred.

The plumbago of the bridge must necessarily be of considerable size in order to have the requisite strength. Owing to its size an appreciable interval, two or three seconds elapses before it is heated sufficiently to ignite the fuze, unless a *very* powerful source of electricity is employed. For this reason it is best to connect the leading wires directly to a Farmer's large machine without using the firing key. Three or four turns of the machine will explode the fuze.

The heat generated is not momentary, but constantly increases.

A priming of mealed powder may hasten the ignition slightly.

TIN-FOIL FUZE.—Lieutenant Pillsbury suggested the use of tin-foil in making an improvised fuze for Farmer's Machine. A large number of experiments have been made with this material at this Station. The results have been highly satisfactory.

Plate V, Figs. 7 and 8, show a convenient form for making an improvized fuze with a tin-foil bridge. A is a wooden plug through which are bored two pairs of small holes, *b*, *b*. A piece of tin-foil is pasted over one end of the plug. Two pieces of small copper wire, about six inches long, have square cornered bights made in them, one leg of each wire being left longer than the other. The short part of the bight is flattened. The ends of the wires are passed through the holes in the wooden plug, one wire to each pair of holes, in such a manner that the flattened part of the wire rests on the tin-foil. The short ends of the wires are twisted around their own longer parts, care being taken to press the wire well down on the foil. The tin-foil is then cut away, leaving only a narrow bridge between the two wires.

The case may be made of paper, wood, or metal; but if the latter is used care must be taken to remove the foil from the edges of the plug, otherwise a short circuit would be formed.

This fuze will ignite fine rifle powder, but it is better to use mealed powder or the composition from the head of a cannon primer as a priming.

THE BRIDGE.—The thinnest foil obtainable should be used. In case the foil should be thick, it will be necessary to increase the length of the bridge.

Figs. *a, b, c,* and *d,* show convenient forms for doing this.

The foil which comes around chewing tobacco is rather thick, and a long bridge must be made. Recent experiments with this foil showed that when the bridge was of the form shown in Fig. C, and nearly that size, the resistance could easily be made as great as 0.2 Ohm.

The strength of current required to fire the fuze did not exceed 2.5 Weber's.

This fuze will fire with both sizes of Farmer's dynamo-electric machine, and with 3 cells Station Battery or its equivalent.

FOREIGN FUZES.

It is exceedingly difficult to obtain any reliable information in regard to the forms of torpedo fuzes at present in actual use by other nations. The fuzes given below are the latest patterns of which any definite descriptions could be procured.

ENGLAND.

ABEL'S COMPOSITION FUZE.—Plate VI, Figs. 1 and 2. This fuze has a wooden case A, of the form shown in Fig. 1, hollowed out for half its length, and having a small hole B, running through its axis, and two more, *c*, *c*, bored parallel to each other on opposite tides of the central one and at right angles to it.

A piece of double-insulated wire, manufactured expressly for these fuzes, is used. It consists of two parallel copper wires, (No. 22, B. W. G.,) separated from each other about 0.06 of an inch, and insulated by a coating of gutta-percha 0.13 of an inch in diameter. A piece of the double-covered wire, about 2 inches long, is taken and the insulation carefully removed from about 1.25 of an inch of each wire at one end. The other extremities of the wires are furnished with clean sectional surfaces, care being taken not to press them into contact during the operation.

About a grain of Abel's priming composition is put into a small cylindrical paper cap, *d*, made to fit the double-covered wires. The insulated ends of the prepared piece of wire is inserted into this cap and well pressed down, so that the exposed sectional ends of the wires shall be in close contact with priming composition. The cap is coated with shellac varnish.

The capped end of the wire thus prepared is inserted into the longitudinal hole in the wooden plug so as to project a short distance into the cavity. The long bared ends of the wires are pressed into the grooves in the rounded end of the plug, and their extremities pushed through the transverse holes and secured there by small copper tubes, which are driven in.

The hollow of the plug is filled with mealed powder and closed with a disc of softened gutta-percha. The complete fuze is coated with black varnish.

PRIMING MATERIAL.—The priming material originally consisted of—

Subphosphide of copper	10 parts.
Subsulphide of copper	45 "
Chlorate of potassa	15 "

The proportion of the ingredients are now varied, in order to produce compositions of different degrees of conductivity and sensitiveness.

In preparing the composition the ingredients are finely powdered and thoroughly mixed, with the addition of a little alcohol.

This composition is very sensitive as a priming material and is a conductor of electricity.

RESISTANCE.—Fuzes in which the same composition is used vary greatly in resistance. In a lot recently measured the resistance ranged from 6,000 to 26,000 Ohms. In measuring and testing it is necessary to use a very delicate galvanometer and a weak battery. If subjected to the action of a very weak current for several hours these fuzes will often fire.

NOTE.—The composition fuzes are all black; they fire with frictional machines, magneto and dynamo-electric machines, and with Voltaic batteries, the strength of the current required depending on the conductivity of the priming material.

ABEL'S PLATINUM WIRE FUZE.—Plate VI, Figs. 3 and 4. This fuze is of the same form as the one above described. The insulation is removed from that part of the double-covered wire which projects into the cavity of the plug. A small piece of cork, *c*, about 0.2 of an inch cube, is placed between the wires, and secured by a seizing of fine thread. Between the ends of the copper wires, which project a short distance beyond the cork, is stretched a bridge of fine platinum wire. This bridge is secured by taking several turns around each copper wire and soldering it. A small piece of gun-cotton is tied around the bridge, and the case is filled with rifle powder, and closed with a plug of gutta percha. The fuze is coated with black varnish.

The Bridge.—The metal used is pure platinum. The diameter of the wire is 0.0062 of an inch; length 0.18 of an inch. The mean resistance of a number of fuzes was found to be 0.029 of an Ohm; strength of current necessary to fire, 3.37 webers.

Priming Material.—The gun-cotton used for the priming is in the form of a loosely twisted yarn. The yarn is passed under the bridge, and an over-hand knot made enclosing it.

NOTE.—The flat end of the platinum wire fuze is colored red, the remainder of the case being black. They fire with both sizes of Farmer's machine and with three cells of Station battery, or its equivalent.

FRANCE.

Composition Fuze.—Plate VI, Figs. 5 and 6, show a composition fuze manufactured by M. Breguet, of Paris, for use with his magneto-electric machine. This fuze is believed to have been, until recently, the service fuze of the French navy.

To the bared ends of a short piece of double-covered wire, *a*, similar to that used in Abel's fuzes, are attached the two short pieces of insulated iron wire, *b b*. The other end of the double-covered wire is inserted into a paper case containing a priming composition. The capped ends of the wires are placed in a wooden case, which is filled with rifle powder, and closed by a cork. The cavities in both ends of the case are filled with a resinous compound.

The resistance of these fuzes is very great, being upwards of 400,000 Ohms.

Note.—These fuzes are colored black; they should fire with all magneto-electric machines, but require at least 50 cells of Station battery.

Platinum Wire Fuze.—Plate VI, Figs. 7 and 8, show the form of the platinum wire fuze manufactured by M. Breguet, and at present used by the French navy. A wooden plug, *a*, has grooves on opposite sides, in which are placed the bared ends of two short pieces of insulated wire. The bridge is secured to the short ends of the wire. This plug screws into a wooden case, *b b*, which is filled with a mixture of mealed and rifle powder. The end of the case is closed by a cork, *c*.

The Bridge.—Platinum wire is used, the diameter being between 0.0018 and 0.0039 of an inch. The length of the wire used for the bridge is nearly an inch.

The peculiarity of this fuze is in the form given to the bridge. The platinum wire is twisted into a spiral, whose diameter is about 0.04 of an inch. Each bridge consists of six or eight convolutions, separated from each other by a distance of only 0.01 of an inch. The object of this form is to introduce a large resistance into each fuze, and also to concentrate the heat produced.

Priming Material.—Collodion is used for the priming material. To render it less liable to crack while drying, the collodion is dissolved in alcohol, and a little turpentine and castor oil are added. The coating must be thin, otherwise it would serve to conduct the electricity.

It is claimed for the priming material that it strengthens the fuze, and prevents the powder from being repelled by the passage of the electric current; and that it also prevents the action of the sulphur of the powder on the copper wires, which is frequently caused by the acid used in soldering the bridge.

Pyroxylin is sometimes introduced between the coated wire and the filling of the case.

AUSTRIA.

Ebner's Composition Fuze.—Plate VI, Figs. 9 and 10 This fuze, adopted by the Austrian service, has a case, A, A, of gutta-percha having two projections B, B, through which the wires pass. The wire is bent into the form of an ∩, and a plug C, made of a mixture of sulphur and ground glass is cast around it just below the bend. The wire is cut at the point *d*, care being taken to make the break a definite size.

Priming Composition.—This composition consists of—

Sulphuret of antimony	1 part.
Chlorate of potassa	1 part.
Powdered plumbago	———

The object of the plumbago is to give the mixture a certain amount of conducting power for testing purposes.

The composition is put into the fuze under pressure, the wires being connected to a very weak battery, having a sensitive galvanometer in the circuit. The pressure is applied so as to obtain, as far as possible, a uniform resistance in each fuze.

PRUSSIA.

The Prussian service uses a platinum wire fuze with a gun-cotton priming, almost identical in construction with the wooden case D. E. igniter of our own service. Plate IV, Fig. 4.

DENMARK.

The fuze adopted by the Danish navy has a spiral platinum wire bridge and collodion priming, and is quite similar to the fuze at present used by the French navy, and shown on Plate VI, Figs. 7 and 8.

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